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Vitalii Morskyi

ANALYSIS OF THE ACCLIMATIZED ORNAMENTAL INTRODUCED WOODY PLANTS FLORA OF CHERNIHIV'S GREEN INFRASTRUCTURE

Віталій Морський

АНАЛІЗ ФЛОРИ АКЛІМАТИЗОВАНИХ ДЕКОРАТИВНИХ ІНТРОДУКОВАНИХ ДЕРЕВНИХ РОСЛИН ЗЕЛЕНОЇ ІНФРАСТРУКТУРИ ЧЕРНІГОВА

ABSTRACT

The study is focused on a comprehensive floristic evaluation of acclimatized ornamental introduced woody plants within the green infrastructure of Chernihiv.

The aim of the work is to assess the current state and determine the prospects for sustainable urban greening of Chernihiv in the context of climate change by analyzing the systematic, geographical, biomorphological and ecological structure of the flora of acclimatized ornamental introduced woody plants.

Methodology. The research was conducted during 2023–2025 across various functional zones of Chernihiv's green infrastructure. The object of study is the acclimatized ornamental introduced woody plants flora. The methodology integrated floristic inventorying (WFO standard), geographical analysis based on the homoclimatic principle, ecological assessment using USDA Hardiness Zones, and invasive risk evaluation following established regional criteria.

Scientific novelty. For the first time, a detailed analysis of the ornamental introduced flora of Chernihiv has been performed, accounting for the massive influx of modern cultivars in the 21st century. The study identifies specific biological indicators of regional climate warming (successful acclimatization of USDA Zone 6A-7A species) and establishes a correlation between the duration of a species' introduction and its invasive potential. The functional role of various functional zones as refugia for climate-resilient exotics is substantiated.

Conclusions. The flora is represented by 115 species, 2 subspecies, and 79 cultivars from 30 families, among which *Rosaceae* and *Fabaceae* predominate. Geographical structure is led by North American (34.78 %) and East Asian (25.22 %) groups. It was found that invasive potential is characteristic primarily of "legacy" species (pre-20th century), while modern cultivars remain ecologically safe. The thriving of taxa like *Sequoiadendron giganteum* and *Hibiscus syriacus* confirms a shift in climate boundaries. Future development of Chernihiv's green infrastructure, according to the 2016 Greening Concept, should prioritize technogenically resilient hybrids and climate-plastic exotics from the 5th and 6th USDA zones.

Key words: dendroflora of Chernihiv, green infrastructure, plant introduction, urban flora, USDA hardiness zones

АНОТАЦІЯ

Дослідження зосереджено на всебічній флористичній оцінці акліматизованих декоративних інтродукованих деревних рослин у межах зеленої інфраструктури Чернігова.

Метою роботи є оцінити сучасний стан та визначити перспективи сталого міського озеленення Чернігова в умовах змін клімату шляхом аналізу систематичної, географічної, біоморфологічної та екологічної структури флори акліматизованих декоративних інтродукованих деревних рослин.

Методологія. Дослідження проводилося протягом 2023–2025 років у різних функціональних зонах зеленої інфраструктури м. Чернігова. Об'єктом вивчення є флора акліматизованих декоративних інтродукованих деревних рослин. Методологія інтегрувала флористичну інвентаризацію (стандарт WFO), географічний аналіз на основі гомокліматичного принципу, екологічну оцінку за зонами зимостійкості USDA та оцінку інвазійного ризику за встановленими регіональними критеріями.

Наукова новизна. Вперше проведено детальний аналіз декоративної інтродукованої флори Чернігова з урахуванням масового припливу сучасних культиварів у XXI столітті. Виявлено специфічні біологічні індикатори регіонального потепління клімату (успішна акліматизація видів зон USDA 6A-7A) та встановлено зв'язок між тривалістю інтродукції виду та його інвазійним потенціалом. Обґрунтовано функціональну роль різних зон як рефугіумів для кліматично стійких екзотів.

Висновки. Флора представлена 115 видами, 2 підвидами та 79 сортами з 30 родин, серед яких переважають *Rosaceae* та *Fabaceae*. У географічній структурі лідирують північноамериканська (34,78 %) та східноазійська (25,22 %) групи. Встановлено, що інвазійний потенціал характерний переважно для «історичних» видів (до XX ст.), тоді як сучасні культивари залишаються екологічно безпечними. Процвітання таких таксонів, як *Sequoiadendron giganteum* та *Hibiscus syriacus*, підтверджує зміщення кліматичних меж. Майбутній розвиток зеленої інфраструктури Чернігова, згідно з Концепцією озеленення 2016 року, має базуватися на пріоритетному використанні техногенно стійких гібридів та кліматично пластичних екзотів 5-ї та 6-ї зон USDA.

Ключові слова: дендрофлора Чернігова, зелена інфраструктура, зони зимостійкості USDA, інтродукція рослин, урбанофлора

Introduction

Ornamental introduced woody plants in urban environments are non-native trees and shrubs intentionally planted for aesthetic appeal, providing crucial ecosystem services like air purification, temperature regulation, and biodiversity enhancement, while also offering structural beauty and habitat. Sjöman et al. (2024) identify a list of current and future challenges that can affect urban trees, including climate change (drought, heat, flooding, storms, wildfires), pests and pathogens, and urban development.

The careful species selection is vital to match urban stresses and avoid invasive potential (Opalko et al., 2025). In arid climate conditions, ornamental woody plants must tolerate an arid climate, high summer heat, low rainfall, and salinized soils, adapting by shortening vegetation periods; *Ulmus pumila* L., *Populus alba* L., *Fraxinus pennsylvanica* Marshall, and *Maclura pomifera* (Raf.) C. K. Schneid. are highly resilient for mass planting, while other species need intensive care, with successful landscaping relying on selecting species with strong stress resistance for microclimate improvement, air purification, and aesthetic appeal (Kurbaniyazov et al., 2025). For Nordic urban green infrastructures, stress resistance (salt, drought, pollution) and genetic diversity are prioritized when selecting trees, with an emphasis on species that thrive in specific harsh urban conditions, such as paved areas (Sæbø et al., 2005).

In urban environments with moderate (temperate) climates, acclimatized introduced woody plants must balance aesthetic value with the ability to withstand unique man-made stressors while providing ecosystem services (Calfapietra et al., 2015; Vogt et al., 2017; Strashok et al., 2025). Global climate change stimulates migration, which increases the number of introduced plant species, as well as those with a status of rarity (Nuzhyna et al., 2023). Esperon-Rodriguez et al. (2024) demonstrate how using urban tree inventories and climate risk metrics can aid in the identification of vulnerable species and locations at high climate risk to prioritise areas for monitoring and assist urban planning.

According to some authors, urban areas are richer in many soil nutrients compared to the surrounding semi-urban and rural habitats and thus facilitate the establishment of non-native plants in urban areas (Zhu & Carreiro, 2024). Results from other studies showed thatmost of the woody species of urban environment require sites medium-poor to medium-rich in nutrients (Horvat et al., 2024).

Sjöman et al. (2024) identify a list of current and future challenges that can affect urban trees, including climate change (drought, heat, flooding, storms, wildfires), pests and pathogens, and urban development.

Thus, a comprehensive flora analysis of acclimatized ornamental introduced woody plants is crucial for creating resilient urban landscapes in temperate zones. This involves taxonomic and biomorphological assessment to ensure structural diversity, ecological analysis to match species with specific urban microclimates, and chronological data to track long-term adaptation. Integrating this multi-faceted floristic evaluation enables proactive urban planning and the selection of plants that thrive amidst environmental shifts.

The green infrastructure of modern cities serves as a critical biological filter and a vital component of urban resilience (EUR-Lex, n.d.). In the context of the temperate zone, the city of Chernihiv represents a unique model for studying urban flora due to its historical green heritage and evolving environmental conditions. The structure of Chernihiv's urban flora and its native components were extensively documented by Zavyalova (2010, 2012a, 2012b), establishing a baseline for botanical diversity. Subsequent research by Pototska (2011) transitioned the focus toward the dendroflora, providing a comprehensive evaluation of gymnosperms and the general state of green spaces in the region.

The management and optimization of these resources have been addressed through various lenses, from the historical restoration of the Regional Botanical Garden (Karpenko & Pototska, 2012) to the development of the «Concept for the Chernihiv city greening» (Pototska, 2017). Recent scientific efforts have increasingly pivoted toward the challenges of the 21st century. Studies by Karpenko et al. (2023, 2025) and Pototska et al. (2025) have explored the ecosystem services provided by street plantings and the physiological adaptation of introduced trees to rapid climate shifts. Furthermore, the emergence of invasive strategies among ornamental species has highlighted the need for rigorous biosecurity management (Lukash et al., 2024a).

Despite this extensive body of work, there remains a critical need for a specialized floristic analysis focused specifically on acclimatized ornamental introduced woody plants. While general dendroflora is documented, a multifaceted analysis encompassing systematic, geographical, biomorphological, ecological, and chronological dimensions of these "immigrant" species has not been fully realized. Understanding the chronological success of past introductions in relation to their current ecological performance is essential for predicting the future stability of urban forests. Therefore, this study aims to fill this gap by providing a comprehensive floristic evaluation of introduced woody taxa, ensuring that Chernihiv's green infrastructure remains functional and aesthetically valuable amidst ongoing climatic and anthropogenic transformations.

The aim of this study is to assess the current state and determine the prospects for sustainable urban greening of Chernihiv in the context of climate. To achieve this aim, the following objectives were defined:

– to inventory and update the systematic structure of introduced woody taxa in the city's main green spaces;

– to analyze the species based on their geographical origin and biomorphological traits to identify dominant adaptive types;

– to perform an ecological assessment of the current state of these plants in relation to modern urban stressors (soil compaction, climate aridization);

– to conduct a chronological analysis of introduction periods to determine the long-term success and longevity of various species;

– to identify promising «future-proof» species for the optimization of Chernihiv's green infrastructure under ongoing climate change.

Materials and methods

The study was conducted during 2023–2025 across the green infrastructure of Chernihiv (Northern Ukraine), encompassing various functional zones: natural-landscape cores (e.g. Regional Landscape Park "Yalivshchyna", Boldyna Gora), street plantings, and residential areas. The object of the study is the flora of 105 taxa (species and cultivars) of ornamental introduced woody plants. Based on the research results using information sources (Marshall, 2009; Shynder et al., 2020; Davydov, 2020b; San-Miguel-Ayanz, 2021; Slyusar, 2021; Zaimenko et al, 2022; Ebben, 2025), the flora summary was compiled (Morskyi & Lukash, 2026).

The research methodology integrated several analytical approaches.

Floristic inventory. Species identification was performed using standard botanical methods, with nomenclature updated according to The World Flora Online (WFO, 2025).

The floristic analysis was conducted using the approaches outlined by Fiaschi et al. (2023).

Systematic and biomorphological analysis. Taxa were classified into families and life forms (trees, shrubs, vines) based on their habit and structural characteristics in urban conditions.

Geographical analysis. The geographical analysis of the flora was conducted by identifying chorological groups and range types according to the methodological principles developed by Kleopov (1990) for the deciduous forest zone. Additionally, the classical phytogeographical structuring approaches of A. I. Tolmachev were applied, following their modern interpretation and implementation in the study of regional Ukrainian floras by Yarova and Fedoronchuk (2015). Depending on their origin, species are divided into North American, East Asian, Western and Central European, and other groups.

Ecological and climate assessment. Tolerance to urban stressors (soil compaction, pollution, pH) was evaluated based on field observations using information sources (Marshall, 2009; Shynder et al., 2020; Davydov, 2020a; San-Miguel-Ayanz, 2021; Slyusar, 2021; Zaimenko et al, 2022; Ebben, 2025). Climate resilience was assessed according to the USDA Plant Hardiness Zones (USDA, 2023).

Chronological analysis. The timing of introduction was established through the documentation of the Municipal Enterprise "Zelenbud" of the Chernihiv City Council and the Educational and Scientific Station of the T.H. Shevchenko National University "Chernihiv Colehium", as well as oral reports and personal information.

Invasiveness of plant species was evaluated based on original field observations and the regional assessments by Zavyalova (2012) and Lukash et al. (2024a, 2024b), following the fundamental conceptual framework for naturalization and invasion stages defined by Richardson et al. (2000) and the standardized environmental impact classification proposed by Blackburn et al. (2014).

Strategic evaluation. The findings were synthesized with the framework of the "Concept for the Chernihiv city greening" (Karpenko et al., 2016) to formulate future management recommendations.

Results and discussion

Analysis of the systematic structure of the decorative introduced dendroflora of Chernihiv indicates a fairly high level of taxonomic diversity. The list of taxa (Table 1) includes 30 families, 70 genera, 115 species, 2 subspecies and 79 cultivars. The leading species richness are *Rosaceae* (27 species), *Fabaceae* (11 species), *Cupressaceae* (10 species) and *Pinaceae* (9 taxa).

A key feature of the modern green infrastructure is the significant saturation with ornamental cultivars (varieties), particularly within the genera *Spiraea*, *Physocarpus*, *Juniperus*, and *Thuja*. For instance, the genus *Spiraea* is represented by highly adaptive taxa such as *S. japonica* with numerous cultivars *('Goldmound', 'Magic Carpet'*, etc.), while the genus *Juniperus* demonstrates broad biomorphological diversity from prostrate forms (*J. horizontalis*) to upright columnar types (*J. scopulorum*). The presence of rare and highly decorative taxa like *Metasequoia glyptostroboides, Sequoiadendron giganteum*, and various *Magnolia* species indicates a high level of successful acclimatization and a shift toward increasing the bio-aesthetic potential of the city's green zones.

The systematic structure of Chernihiv's ornamental introduced dendroflora is characterized by a distinct dominance of several key families. The *Rosaceae* family acts as the absolute leader, represented by highly functional and decorative genera such as *Spiraea, Cotoneaster, Prunus*, and *Malus*. The *Cupressaceae* family forms the backbone of the city's evergreen coniferous infrastructure, while Fabaceae (notably *Robinia, Gleditsia*, and *Amorpha*) plays a crucial role in maintaining soil fertility through nitrogen fixation and ensuring high resistance to urban stressors. The *Sapindaceae* family is also significant, primarily through the wide use of *Acer* and *Aesculus* species.

A defining characteristic of the current flora is its extensive cultivar diversity. Taxa such as *Physocarpus opulifolius* (6+ cultivars) and *Thuja occidentalis* (6+ cultivars) demonstrate high intra-specific variety, which is critical for modern landscape design and architectural zoning. Furthermore, the successful cultivation of exotic "relicts" like *Sequoiadendron giganteum* and *Metasequoia glyptostroboides* in Chernihiv serves as a powerful indicator of either shifting climate zones or the creation of favorable microclimatic urban niches that allow for high levels of physiological adaptation.

Table 1

The list of the acclimatized ornamental introduced woody plants of the Chernihiv's green infrastructure flora

Families	Species, subspecies, cultivars
Anacardiaceae R.Br.	*Cotinus coggygria* Scop. *Rhus typhina* L.
Araliaceae Juss.	*Hedera helix* L.
Berberidaceae Juss.	*Berberis thunbergii* DC., *B. thunbergii 'Admiration', 'Atropurpurea Nana', 'Golden Rocket', 'Orange Rocket', 'Red Rocket', 'Maria', 'Green Ornament'*
Betulaceae Gray	*Betula utilis* D.Don
Bignoniaceae Juss.	*Campsis radicans* (L.) Seem. ex Bureau *Catalpa bignonioides* Walter *C. bignonioides 'Nana'*
Buddlejaceae K.Wilh.	*Buddleja davidii* Franch.

Families	Species, subspecies, cultivars
Buxaceae Dumort.	*Buxus sempervirens* L.
Caprifoliaceae Juss.	*Kolkwitzia amabilis* Graebn. *Lonicera caprifolium* L. *L. italica* Schm., *L. notha* Zabel, *L. tatarica* L. *Weigela florida* (Bunge) A.DC., *W. florida 'Red Prince', 'Lucifer'*
Celastraceae R.Br.	*Euonymus fortunei* (Turcz.) Hand.-Mazz., *E. fortunei 'Emerald Gaiety'*
Cornaceae Bercht. ex J.Presl	*Cornus alba* L., *C. alba 'Elegantissima'*
Cupressaceae Gray *Cupressaceae Gray*	*Juniperus chinensis* L., *J. chinensis 'Kuriwao Gold', 'Stricta', 'Stricta'* *J. horizontalis* Moench, *J. horizontalis 'Prince of Wales', 'Lime Glow', 'Blue Chip'* *J. × pfitzeriana* (Späth) P.A.Schmidt *'Old Gold', 'Daub's Frosted', 'Golden Saucer', 'Mint Julep'* *J. sabina* L., *J. sabina 'Tam No Blight', 'Tamariscifolia'* *J. scopulorum* Sarg. *'Skyrocket'* *J. virginiana L., J. virginiana 'Hetz'* *Metasequoia glyptostroboides Hu & W.C.Cheng* *Sequoiadendron giganteum* (Lindl.) J.Buchholz *Thuja occidentalis* L. *Th. occidentalis 'Smaragd', 'Little Gem', 'Danica', 'Miky', 'Globosa', 'Woodwardii', 'Smaragd'* *Thuja plicata* Donn ex D.Don
Fabaceae Juss.	*Amorpha fruticosa* L. *Caragana arborescens* Lam. *Cercis canadensis* L. *Colutea arborescens* L. *Cladrastis canadensis* Mill. *C. kentukea* (Dum.Cours.) Rudd (*Cladrastis lutea* Neogenyton) *Gleditsia triacanthos* L. *Laburnum anagyroides* Medik. *Robinia pseudoacacia* L., *R. pseudoacacia 'Umbraculifera'* *Robinia viscosa* Michx. ex Vent. *Wisteria frutescens* (L.) Poir.
Fagaceae Dumort.	*Quercus palustris* Münchh., *Q. palustris 'Green Pillar'* *Q. rubra* L.
Hydrangeaceae Dumort.	*Deutzia scabra* Thunb. *Hydrangea paniculata* Siebold, *H. paniculata* Siebold *'Pinky Winky', 'Polar Bear', 'Sandae Fraise', 'Vanille Fraise'* *Philadelphus coronarius* L.
Juglandaceae DC. ex Perleb	*Juglans mandshurica* Maxim.
Magnoliaceae Juss.	*Liriodendron tulipifera* L. *Magnolia hybrida* Dippel *'Susan'* *M. kobus* DC. *M. stellata* (Siebold & Zucc.) Maxim. *'Royal Star'*
Malvaceae Juss.	*Hibiscus syriacus* L. *Tilia europaea* L., *T. europaea 'Pallida', 'Zwarte Linde'* *T. platyphyllos* Scop.
Oleaceae Hoffmanns. & Link	*Forsythia viridissima* Lindl. *Forsythia suspensa* (Thunb.) Vahl *Forsythia intermedia* Zabel *Fraxinus angustifolia* Vahl, *F. angustifolia 'Raywood'* *F. pennsylvanica* Marshall *Ligustrum vulgare* L. *Syringa josikaea* J.Jacq. ex Rchb. *S. vulgaris* L.

Families	Species, subspecies, cultivars
Phyllanthaceae Martinov	*Securinega suffruticosa* (Pall.) Rehder
Pinaceae Spreng. ex Rudolphi	*Abies alba* Mill. *Larix decidua* (L.) Mill. *Picea abies* (L.) H.Karst. *'Nidiformis'* *P. omorika* (Pančić) Purk. *P. pungens* Engelm., *P. pungens 'Kaibab', 'Glauca'* *Pinus banksiana* Lamb. *P. mugo* Turra *'Mughus', 'Varella'* *P. nigra* J.F.Arnold *subsp. nigra* *P. strobus* L.
Platanaceae T.Lestib.	*Platanus hispanica* Münchh.
Rosaceae Juss.	*Amelanchier canadensis* (L.) Medik. *A. ovalis* Medik. *A. spicata* (Lam.) K.Koch *Chaenomeles japonica* (Thunb.) Lindl. ex Spach *C. speciosa* (Sweet) Nakai *Cotoneaster dammeri* C.K.Schneid., *C. dammeri 'Major'* *C. horizontalis* Decne. *C. acutifolius* Turcz. *C. × suecicus* G.Klotz *'Coral Beauty'* *Dasiphora fruticosa* (L.) Rydb.(*Potentilla fruticosa* L.) *Malus hybrida* Loisel. *'Evereste'* *M. toringo* Nakai *'Freja'* *Physocarpus opulifolius* (L.) Maxim., *P. opulifolius 'Dart's Gold', 'Red Baron','Red Esquire', 'Diabolo', 'Luteus', 'Midnight'* *Prunus cerasifera* Ehrh., *P. cerasifera 'Nigra'* *P. cerasifera* subsp. pissardii (Carrière) Dostál
Rosaceae Juss.	*P. serotina* Ehrh. *P. serrulata* Lindl. 'Kanzan' *P. virginiana* L. *Pyracantha angustifolia* (Franch.) C.K.Schneid. *Rubus odoratus* L. *Sorbaria sorbifolia* (L.) A.Braun, *S. sorbifolia 'Sem'* *Sorbus intermedia* Maly *S. quercifolia* hort. *Spiraea betulifolia* Pall. *'Island'* *S. × cinerea* Zabel *'Grefsheim'* *S. japonica* L.f., *S. japonica 'Anthony Waterer', 'Candlelight', 'Golden Princess', 'Crispa', 'Goldmound', 'Magic Carpet'* *S. vanhouttei* (Briot) Zabel
Rutaceae Juss.	*Phellodendron amurense* Rupr. *Ptelea trifoliata* L.
Salicaceae Mirb.	*Populus deltoides* W.Bartram ex Marshall *Salix alba* L. *'Chermesina* *Salix integra* Thunb. *'Hakuro-Nishiki'*
Sapindaceae Juss.	*Acer × freemanii* A.E.Murray *'Autumn Blaze', 'Celzam'* *A. negundo* L., *A. negundo'Variegatum'* *A. rubrum* L., *A. rubrum 'Brandywine', 'Red Sunset', 'Redpointe', 'Sun Valley'*
Sapindaceae Juss.	*A. saccharinum* L. *A. truncatum* Bunge *'Pacific Sunset'* *Aesculus carnea* Zeyh. *A. hippocastanum* L.

Families	Species, subspecies, cultivars
Schisandraceae Blume	*Schisandra chinensis* (Turcz.) Baill.
Solanaceae Juss.	*Lycium barbarum* L.
Taxaceae Gray	*Taxus baccata* L., *T. baccata 'Fastigiata Robusta'*
Ulmaceae Mirb.	*Ulmus pumila* L.
Vitaceae Juss.	*Vitis amurensis* Rupr. *Parthenocissus quinquefolia* (L.) Planch

The analysis of the geographical structure of Chernihiv's ornamental introduced flora reveals a clear disproportion in the distribution of donor regions (Fig. 1). Species of North American origin are predominant (40 species; 34.78 %), including *Robinia pseudoacacia, Gleditsia triacanthos, Acer saccharinum, Rhus typhina, Catalpa bignonioides, Prunus serotina, Sorbus quercifolia, Physocarpus opulifolius*, etc. This dominance aligns with the Zavyalova (2010) data and is scientifically grounded in the homoclimatic principle (Kuznetsov, 2008). According to Sjöman et al. (2024), the climatic parameters of Eastern North America (temperature amplitudes and precipitation patterns) closely mirror those of the temperate zone conditions, including Ukraine, providing these species with pre-adapted physiological mechanisms for successful naturalization.

Species of East Asian origin (29 species; 25.22 %) serve as the second major pillar, contributing highly ornamental taxa such as *Magnolia kobus, Magnolia stellata, Metasequoia glyptostroboides, Ginkgo biloba, Buddleja davidii, Weigela florida*, and *Hibiscus syriacus*. The predominance of introduced woody species of East Asian origin in the green infrastructure of Chernihiv is primarily attributed to the exceptionally high floristic diversity and broad ecological adaptations of the East Asian dendroflora as a whole. This phenomenon reflects the region's evolutionary history as a stable glacial refugium, which allowed for the preservation of numerous ancient lineages and the development of high adaptive plasticity (Marsh et al., 2009; Cires, 2018). Pototska (2012) highlights that Asian species often occupy specialized ecological niches in urban parks where they provide maximum aesthetic impact.

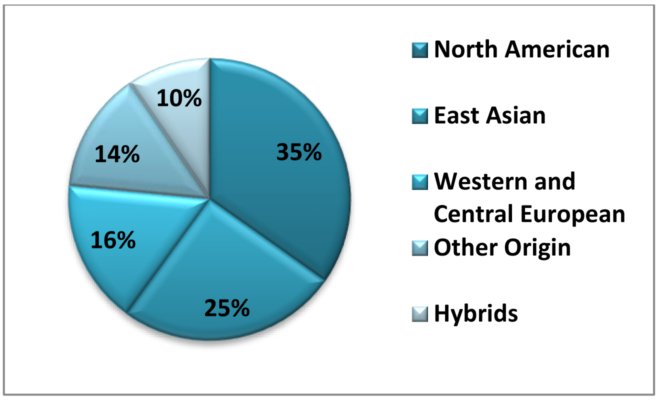

Fig. 1. Percentage distribution of geographical groups within the ornamental introduced dendroflora of Chernihiv. The dominance of North American and East Asian species (combined 60%) highlights the effectiveness of the homoclimatic selection principle in urban greening

Crucially, the study identifies several minor geographical fractions, which, despite their low species count, add unique structural and biological diversity to the urban landscape: Western and Central European (*Juniperus sabina, Abies alba, Larix decidua, Laburnum anagyroides, Philadelphus coronaries, Tilia europaea, T. platyphyllos, Syringa josikaea, Picea abies, P. omorika, Pinus nigra*), Balkan-Mediterranean (*Aesculus hippocastanum, Syringa vulgaris, Fraxinus angustifolia*), European-Siberian and Central Asian (*Caragana arborescens, Buxus sempervirens, Cotinus coggygria, Hedera helix, Colutea arborescens*), Far Eastern (*Schisandra* *chinensis, Phellodendron amurense, Juglans mandshurica*), Himalayan and High-Mountain (*Betula utilis*).

The discussion also touches upon the increasing role of horticultural hybrids (11 taxa; about 10 %), such as *Juniperus × pfitzeriana, Acer × freemanii, A. truncatum, Platanus hispanica, Lonicera × notha, Aesculus carnea, Forsythia intermedia, Cotoneaster × suecicus, Malus hybrida* Loisel. *'Evereste', Spiraea × cinerea*. These anthropogenic forms are prioritized in modern green infrastructure for their sterility and enhanced resistance to urban heat islands (Vogt et al., 2017). However, the invasive potential of certain North American species, such as *Acer negundo* and *Prunus serotina*, remains a point of concern (Lukash et al., 2024a). On the other hand, species that were introduced at the end of the 20th century – the 21st century do not yet show invasive activity or "hide" it. For example, the *Robinia viscosa* artificial territorial isolation from natural plant communities (the default minimum population separation distance is 2 km: range 1.50–2.67 km) and very low generative potential in the conditions of introduction of the Chernihiv city's green infrastructure do not allow this species to actively demonstrate invasive properties.

The chronological analysis of Chernihiv's ornamental dendroflora reveals three distinct waves of introduction, each characterized by different ecological strategies and levels of biological risk. We have identified 3 introduction period in the Chernihiv city (Fig. 2).

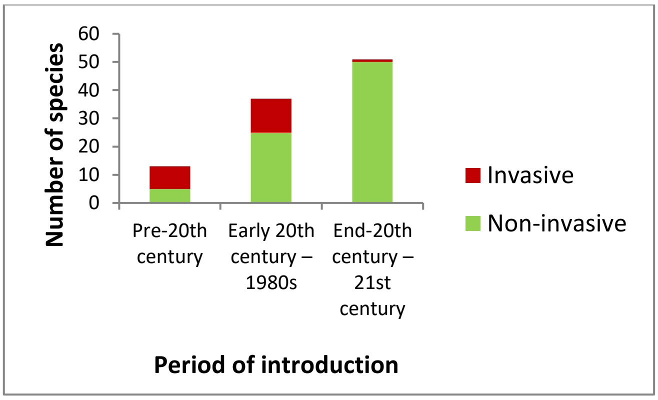

Fig. 2. Distribution of introduced woody species by periods of introduction and their invasive potential. The height of the columns represents the total species richness, while the segments highlight the ratio of invasive to non-invasive taxa

1. The introduction "core" forming period (pre-20th century: mid-18th to late 19th centuries). This stage involves the establishment of historical species in Chernihiv – taxa with a long history of cultivation that formed the backbone of the urban landscape. Within this group, pioneer species such as Robinia pseudoacacia, Acer negundo, Aesculus hippocastanum, and Syringa vulgaris played a key role. These "pioneers" represent the first successfully introduced exotics, characterized by high ecological plasticity and the ability for rapid initial colonization of urban ecotopes. Critically, most currently identified invasive species belong to this early introduction group. Prolonged acclimatization (over 150 years of residence time) has allowed taxa like Robinia pseudoacacia and Acer negundo to fully overcome reproductive barriers and naturalize, often exhibiting aggressive expansion into the spontaneous urban flora (Zavyalova, 2012a).

2. The Moderate introduction period (early 20th century – 1980s). This wave was dominated by functional resilience and mass-planting. Species like *Catalpa bignonioides, Quercus rubra, Fraxinus pennsylvanica, Rhus typhina*, and *Ulmus pumila* were introduced during this time. Today, many of these (marked "+" in the flora summary (Morskyi & Lukash, 2026) demonstrate high invasive potential, particularly *Quercus rubra* and *Fraxinus pennsylvanica*, which effectively outcompete native species in urban woodlands like "Yalivshchyna" (Karpenko et al., 2023; Lukash et al., 2024a).

According to a 2012 study by Karpenko and Pototska, the mid-20th century to 1980s in Chernihiv was characterized by a scientifically driven approach to urban greening (Karpenko & Pototska, 2012). The establishment and development of the Chernihiv City Botanical Garden during this period were crucial for purposefully enriching the city's dendroflora (Karpenko & Pototska, 2012).

3. The Modern "cultivar explosion" (end-20th century – 21st century). The last 35 years are marked by a massive influx of decorative cultivars and exotic taxa (*Metasequoia, Sequoiadendron, Magnolia spp.*, and various cultivars of *Spiraea, Berberis*, and *Hydrangea*). Notably, none of the recently introduced cultivars currently demonstrate invasive potential. This is likely due to specialized breeding for sterility and their higher demands for maintenance. The successful presence of *Wisteria frutescens* and *Liriodendron* in Chernihiv is a direct result of recent climate warming, as noted by Karpenko et al. (2025).

The biomorphological structure of of the acclimatized ornamental introduced woody plants flora of Chernihiv's green infrastructure (Fig. 3) ensuring multi-layered and structurally stable green infrastructure. The analysis reveals a balanced ratio between phanerophytes (trees) and nanophanerophytes (shrubs), with a minor but functional inclusion of lianes. Large trees (15–30 m) like *Quercus rubra, Acer saccharinum*, and *Gleditsia triacanthos* form the upper canopy and provide maximum shading. The middle layer (5–15 m) is dominated by highly decorative species such as *Catalpa bignonioides, Magnolia kobus*, and *Rhus typhina*. The lower layer (up to 2–3 m) consists of a wide variety of shrubs, primarily cultivars of *Spiraea, Berberis*, and *Physocarpus*, which are essential for architectural zoning.

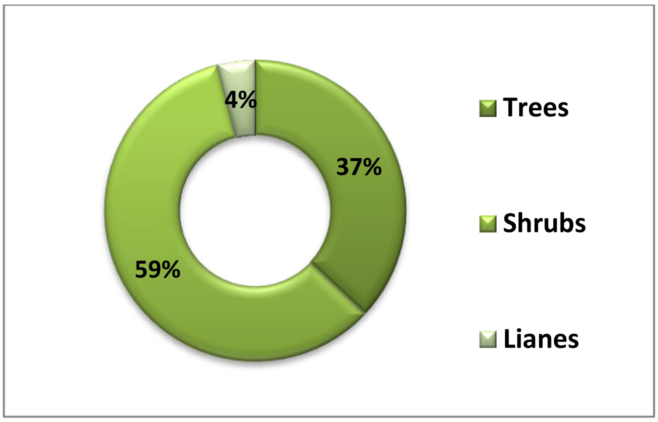

Fig. 3. Biomorphological structure of the introduced dendroflora of Chernihiv (calculated for 196 taxa, including 115 species, 2 subspecies and 79 cultivars). The dominance of shrubs (59%) reflects the modern trend towards high-density decorative landscaping using diverse cultivars

It shoud be noted the architectural diversity of crowns. A notable trend in Chernihiv's modern greening is the use of cultivars with specialized crown shapes. These range from columnar (*Juniperus scopulorum 'Skyrocket', Quercus palustris 'Green Pillar'*) to globular (*Catalpa bignonioides 'Nana', Thuja occidentalis 'Danica'*) and pendulous forms. This allows for precise landscaping in restricted urban spaces.

The acclimatized ornamental introduced woody plants flora of Chernihiv's green infrastructure characterized by phenological and aesthetic dynamics. The decorative appeal is maintained throughout the year. The early spring season is marked by the flowering of *Magnolia spp*. and *Prunus cerasifera*, while midsummer is dominated by *Hibiscus syriacus* and *Buddleja davidii*. Special attention is given to autumn coloration: taxa like *Rhus typhina, Acer rubrum, Cotinus coggygria*, and *Quercus rubra* provide vibrant red and gold accents, significantly enhancing the city's visual quality during the late vegetation period.

The structural beauty, e.g. winter ornamentation, of the dendroflora is supported by diverse bark textures (e.g., *Betula utilis, Phellodendron amurense*) and the persistence of fruits (e.g., *Symphoricarpos, Pyracantha, Catalpa* pods), ensuring that the green infrastructure remains aesthetically functional even during the dormant season.

Beyond their structural and ornamental roles, the introduced dendroflora of Chernihiv significantly enhances the city's green infrastructure through its resource potential. According to Lukash et al. (2024b), the 18 of adventive tree and shrub species in the urban environment possesses medicinal properties. The integration of such multifunctional taxa into green spaces not only provides aesthetic and ecological benefits but also creates a valuable base for provisioning ecosystem services, further justifying the diversification of the city's green infrastructure dendrological assortment.

The analysis of ecological parameters indicates that Chernihiv's introduced flora is dominated by heliophytes (54 species; 47.0 %) and xeromesophytes (41 species; 35.7 %), representing a localized response to the «urban heat island» effect. This trend aligns with the findings of Calfapietra et al. (2015), who argued that urban environments act as a filter, favoring species with high transpiration efficiency.

Our findings regarding the prevalence of alkaliphilic species (*Syringa vulgaris, Gleditsia triacanthos*) corroborate the observations of Zavyalova (2010), who noted the high adaptive capacity of North American exotics in the carbonated soils of Polesia. This "alkaline shift" in urban environments, as discussed by Zhu & Carreiro (2024), provides a competitive niche for introduced taxa, while acidophilic species (*Acer rubrum, Abies alba*) remain confined to specialized park zones.

The exceptional gas tolerance of the North American fraction (e.g., *Thuja occidentalis, Picea pungens, Robinia pseudoacacia*) supports the plant selection for greening strategy proposed in the "Concept for the Chernihiv city greening" (Karpenko et al., 2016; Pototska, 2017). Furthermore, the use of pathogen-resistant cultivars (*Malus 'Evereste', Aesculus × carnea*) represents a transition to "smart" green infrastructure, addressing the vulnerability of traditional urban trees to pests like the leaf miner, as highlighted in Karpenko et al. (2025).

Important are climate indicators – compliance with winter hardiness zones (USDA, 2023). The thriving of Zone 6A and 7A species (*Sequoiadendron giganteum, Hibiscus syriacus, Wisteria frutescens*) is the most significant point for discussion. Historically, such taxa were considered "risky" for Northern Ukraine. However, as demonstrated by Esperon-Rodriguez et al. (2022, 2024) and Karpenko et al. (2025), the shifting climate limits allow for the expansion of the decorative assortment. While the "iron fund" remains Zone 3–5 (e.g., *Thuja occidentalis, Abies alba, Ulmus pumila, Aesculus hippocastanum, Acer × freemanii*), the integration of Zone 6–7 species marks a definitive biological marker of regional warming.

The spatial distribution of introduced woody plants in Chernihiv reflects a complex interplay between historical introduction efforts and contemporary ecological filtering.

Firstly, exotic refugia are a kind of "adaptive laboratories". The concentration of rare exotics (*Metasequoia, Sequoiadendron, Wisteria*) in the "Yalivshchyna" park (Educational and Scientific Station of the T.H. Shevchenko National University "Chernihiv Colehium") is more than a botanical collection; it serves as a "testing ground" for climate resilience. The coexistence of these solitary "climate migrants" with massive naturalized communities of *Robinia pseudoacacia, Prunus serotina*, and *Prunus virginiana* suggests a dualistic role for such hubs: while they preserve high-value aesthetics, they also act as potential epicenters for biological invasions. In contrast, the use of *Cotinus coggygria* and *Lycium barbarum* on the Boldyna Gora and Yeletsa Gora slopes demonstrates a successful functional transition where ornamental plants fulfill critical anti-erosion roles, stabilizing the city's historical topography.

Secondly, invasive dendroflora corridors oppose ecological stability. The dominance of *Acer negundo* and *Amorpha fruticosa* in the Desna floodplains (Kordivka and Liskovytsia) highlights a significant management challenge. These riparian corridors facilitate the rapid spread of "legacy" species, which often outcompete native flora. This observation sparks a debate: should green infrastructure prioritize these highly adaptive "survivors" for their carbon sequestration, or should they be managed as threats to local biodiversity?

Thirdly, there is a shift towards "technogenic aesthetics": In the city center, the replacement of traditional species with systematic group plantings of cultivars (*Thuja 'Smaragd', Spiraea* hybrids) signals a shift toward high-density, low-maintenance landscaping. This trend reflects a pragmatic response to the harsh urban environment (soil compaction, radiant heat), where the reliability of a cultivar often outweighs the ecological benefits of a botanical species.

Fourthly, tree species provide peripheral reclamation of green infrastructure. The presence of Ulmus pumila along railways and Lycium barbarum in industrial zones (areas of the thermal power plant, former worsted and cloth mill and chemical fiber plant) underscores their role in technogenic stabilization. These hardy taxa act as "ecosystem engineers", thriving where native species fail, thus providing essential green cover in degraded suburban peripheries.

Based on the results of this study and the comprehensive framework established in the "Concept for the Chernihiv city greening" (Karpenko et al., 2016), the enrichment of the city's dendroflora should prioritize a transition from spontaneous naturalization to scientifically guided selection. Our analysis confirms that future prospects lie in the integration of highly decorative and technogenically resilient cultivars of the 5th and 6th USDA zones, which have already demonstrated successful acclimatization. Strategic enrichment should focus on expanding the use of climate-plastic taxa from the North American and East Asian fractions that provide maximum ecosystem services – such as thermal regulation and air purification – without posing an invasive risk. According to the 2016 Concept, prioritizing pathogen-resistant hybrids (e.g., *Aesculus × carnea, Acer × freemanii*) and relict exotics in protected microclimatic niches will not only increase biodiversity but also ensure the long-term biological stability of Chernihiv's green infrastructure amidst ongoing climatic transformations.

Conclusions

The ornamental introduced dendroflora of Chernihiv's green infrastructure is represented by 115 species, 2 subspecies, and 79 cultivars from 30 families. The systematic structure is dominated by the *Rosaceae, Fabaceae*, and *Cupressaceae* families, which form the decorative and functional core of the city's urban forest.

Geographical analysis reveals the dominance of North American (34.78 %) and East Asian (25.22 %) groups. The success of these "immigrant" species is scientifically grounded in the homoclimatic principle, where the climate of the donor regions matches the temperature and moisture regimes of Northern Ukraine.

Chronological monitoring identified three waves of introduction. It was established that invasive potential (e.g., *Acer negundo, Robinia pseudoacacia, Amorpha fruticosa*) directly correlates with the duration of stay in the region (the "lag phase"), while modern cultivars of the 21st century currently pose no biological risk.

The successful acclimatization of species from USDA Zones 6A and 7A (*Sequoiadendron giganteum, Hibiscus syriacus, Wisteria frutescens*) serves as a definitive biological indicator of regional climate warming. This shift allows for the expansion of the urban assortment to include more warm-temperate flora.

The biomorphological structure is characterized by a prevalence of shrubs (59 %) over trees, reflecting a modern trend toward high-density, cultivar-based landscaping. Spatially, the Regional Landscape Park "Yalivshchyna" remains the primary hub for acclimatization, while central urban zones are increasingly being optimized with technogenically resilient hybrids.

According to the "Concept for the Chernihiv city greening" (2016), the strategic perspective for enriching the city's green infrastructure lies in the targeted use of pathogen-resistant cultivars and climate-plastic exotics that maximize ecosystem services while maintaining high aesthetic value.

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Декларація про генеративний штучний інтелект і технології на основі штучного інтелекту в процесі написання / Declaration on Generative Artificial Intelligence and AI-enabled Technologies in the Writing Process

Генеративний штучний інтелект застосовувався під час кількісних обрахунках даних конспекту флори та для перевірки правопису англійською мовою. Після використання цього інструменту автор ретельно переглянув та відредагув вміст за потреби та несе повну відповідальність за остаточну опубліковану версію / Generative Artificial Intelligence was used during quantitative calculations of flora synopsis data and for spell checking in English. Following the application of this tool, the author thoroughly reviewed and edited the content as necessary and take full responsibility for the final published version.

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Information about the author:

Morskyi V. [in Ukrainian: **Морський В.],** Ph. D. student[1], Head of the enterprise[2], email: vitaliymorskoy.cn@gmail.com
ORCID: 0009-0000-2465-6731

[1]Department of Ecology, Geography and Nature Management, T.H. Shevchenko National University "Chernihiv Colehium"
53 Hetmana Polubotka Street, Chernihiv, 14013, Ukraine

[2]Municipal Enterprise "Zelenbud" of the Chernihiv City Council
168-A Mykhayla Hrushevskoho Avenue, Chernihiv, 14034, Ukraine